A Knowledge-Based Approach for the Implementation of a SDSS in the Partenio Regional Park (Italy)

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Abstract. The paper recommends a methodology for data gathering and processing through the spatial analysis techniques and the combinatorial multi-criteria procedure of Weighted Linear Combination (WLC). The purpose concerns the spatial problem structuring in a complex decisional context lacking in the geographical dataset. The processing of data and information provided by VGIs and Open Systems is crucial for the enrichment of spatial datasets in these circumstances, but it is advisable to make attention about the data reliability and the known problems of the geographic dataset, i.e. Modifiable Areal Unit Problem (MAUP). The method was tested with the case study of 27 Municipalities around the Partenio Regional Park, in the South of Italy. Within the SDSS, the multidimensional landscape's indicators were combined with data gathering on the field, in order to build an evolving informative system. A multidimensional approach, focused on the recognition of environmental, social, economic and cultural resources, was chosen providing some strategies of enhancement for the overviewed landscape of the Park. The evaluation of the policy and actions for the examined regions generated scenario-maps through multi-criteria procedures and GIS tools.

Keywords: Landscape · Spatial Decision Support System (SDSS) · Volunteered Geographic Information (VGIs) · Weighted Linear Combination (WLC) · Spatial multi-criteria analysis

1 Introduction

The paper introduces an application of a Spatial Decision Support System (SDSS) for the landscape evaluation, focused on the development of tourism and recreation services in a region around a natural park, the Partenio Regional Park, in the South of Italy. The decision problem examines many issues concerning the relationships and trade-off among economic, social, environmental and cultural values. In order to investigate the different components, the recent literature recommends gathering hard and soft data about the region, understanding the spatial effects of a decision on the landscape (Cerreta et al. 2014; Fusco Girard et al. 2014) and combining institutional data with open source. During the last twenty years, the progress in remote-sensing and power computing extended the spatial component evaluation to the decision-making

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process. Moreover the spatial analysis tools provided by Geographic Information System (GIS) aid the decision-maker (DM) in the data management and analysis of spatial features, in the solution of ill-structured problems in an iterative way, in the scenario evaluation, in report generation and visualization of spatial indicators (Sugumaran and de Groote 2010). Including the multidimensional landscape features within the SDSS procedures is a practice that can be continuously improved and empowered (Cerreta and Fusco Girard 2016). An open issue concerns the spatial problem structuring in a complex decisional context where institutional geographic dataset can lack. Nowadays new open-source software for the production of digital geographic information are widely available and everybody can create his own maps through Volunteered Geographic Information (Goodchild and Li 2012). This skill makes inhabitants more aware of their place and increases geographic data for that territory. One of the main issues regards how to relate institutional data with those produced by open-source's users. This stage is critical for the decision-making process since far more information can be made explicit and available to public debate, increasing, as well, the evaluation transparency (Golub 1997; van der Sluijs 2002). Always more frequently, traditional and new dataset are being used in the SDSS, trying to overcome the lack of geographic data. OpenStreetMap is the best-known platform to create an alternative to the products of official agencies and exported data can be used to provide geographic information on non-spatial indicators too. With its normative, spatial, temporal, environmental, cultural, social, and cognitive features, the landscape becomes the framework where planning and project responses can be shaped.

The first part of the paper (Sect. 2) defines the literature review; the second one (Sect. 3) explains the methodological framework of the SDSS; the third (Sect. 4) shows the study case and the outcomes to test the methodological framework; while the fourth (Sect. 5) concludes about the VGI usefulness in policy-making and landscape planning.

2 A Spatial Decision-Making Process for the Landscape Evaluation. A Literature Review

The increasing complexity of landscape planning and policy-making is related to the impacts of the urbanization processes, the irregular development in spatial planning and the growth of the big data. In this context, many authors report the lack of coordination and adoption of advanced technologies to share information (Li et al. 2013).

On the other hand, the landscape knowledge in a decisional context lacking in geographical data is a critical phase of the spatial decision-making processes since it is necessary to guarantee openness and sharing also in the evaluation processes (Golub 1997; van der Sluijs 2002). It is possible to consider the geographical dataset as a segment of a knowledge-based system that aids the DM for sharing strategies of development and transformation/conservation of the landscape characters. Indeed, geographical data implementation within the landscape evaluation aims the community at identifying own landscape; analysing characteristics, dynamics of transformation and pressures; monitoring environmental and anthropic systems; identifying the values that the people assign to the landscape. Moreover, the representation of the territorial system and the processes simulation are two critical models for the landscape evaluation according to Steinitz's Geodesign framework (Steinitz 2012; Cocco et al. 2015).

The spatial feature add-on within the Decision Support System (DSS), making explicit the relationships between the socio-economic and geo-morphological characteristics of the landscape, aids to understanding the transformation processes of the territory and to identify actions, tactics, and strategies of development (Murgante et al. 2011; Attardi et al. 2014). Moreover, the PGIS tools and the multi-criteria methods integrated to GIS software simplify the spatial evaluations and they aim to convert the qualitative judgments to measurable functions through the landscape metrics approach (Brown and Weber 2011). There are many utilities using spatial data, i.e. visualization and data mapping, proactive communication of critical issues, decision-making simplification, etc. However some care is indispensable about the choice of a consistent spatial reference frame and fixed scale of analysis. Indeed the misunderstanding of the Modifiable Areal Unit Problem (MAUP) can compromise the spatial statistics and the final results of the analysis (Openshaw 1983). In presence of census data, moreover, the unit of aggregation for sampling must be evaluated such as household, neighbourhood or country scale. It is really important to understand that the choice of a different scale can lead to completely different outcomes because of different patterns and relationships within the spatial features (O'Sullivan and Unwin 2010). According to Malczewski (2006), the spatial evaluation criteria can be classified into two macro-category: explicitly and implicitly spatial criteria. The first criteria are composed by inherently spatial data, i.e. geomorphology, natural areas, etc., while the latter use the geographic features in order to transfer a spatial representation of themselves, i.e. the ecological integrity index, the number of employers in tourism per census zone, etc. In this way, both the criteria aid the experts to achieve spatial representation of no spatial explicitly indicators to broaden and improve the knowledge of the landscape.

3 The Methodological Steps of the Knowledge-Based Approach

The purpose of the research aims at forecasting new scenario of the suitability for the touristic development and safeguarding the local potentials and environmental assets. The management of the development and the identification of new strategies require a multidimensional approach, in order to merge different components aiming at supporting the identification of innovative place-based actions (Cerreta 2010).

The transformations characterizing the landscape and local systems depend on multiple factors, such as demographic, social and professional changes within the population; the outplacement in new houses and workplaces; the changes of the specialization; the shift of the transportation and communications both in infrastructural and functional way (Istat 2015). The modelling phase of the SDSS for the landscape of "Partenio" generated the spatial indicators using both spatial explicitly and implicitly criteria. Both the raster and vector-based approach was performed in order to produce spatially referenced data and indicators able to describe real-world features in a virtual environment. Moreover, the geographical dataset architecture allowed to manage numerous and heterogeneous data and to produce useful changing scenario (Cerreta and Poli 2013). Specifically, the variety of information picked was classified into six main domains that characterize the Smart Cities (Economy, Environment, People, Living, Mobility and Governance). The six domains identified the physical, economic, intellectual and social capitals for the development of a territory (Giffinger and Haindl 2007) in order to reach the sustainable use of resources. Lastly, any spatial geo-statistics were performed in order to produce new indicators bridging the gap due to the lack of the geographical data and updates. Specifically, the SDSS was structured in the following steps (Fig. 1):

1. "Data gathering" concerns the selection of the data for the study area through various sources, i.e. the field research, the Web, the surveys.
2. "Spatial data representation" aims at building a representation model in GIS environment.
3. "Spatial indicators" aims at the data processing and classification of the indicators in six domains according to Smart Cities approach.
4. "Normalization" of the indicators have been done in order to make homogeneous the values for the next evaluation phase.
5. "Data processing and clustering" step uses the conversion tool "shape to raster" to elaborate suitable data.
6. "Reclassify" of data was performed in order to give semantic judgments to the values according to a scale from low to very high.
7. Multi-criteria method "WLC" was applied to obtain the overlay maps.
8. "Smart maps" shows the weakness and potential of the study area.
9. "Weighting" step was performed through "swing weight method" (Bodily 1985).
10. "Scenario" simulation was run and two final maps were performed.

In this way, the complex problems can be analysed simultaneously in a "what-if" perspective because of the power computing, knowledge domains and organizational skills of ICT.

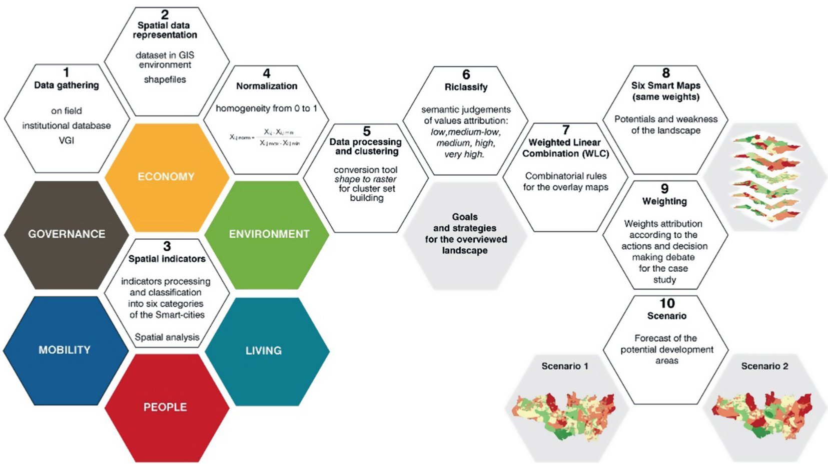

Fig. 1. Methodological framework: steps and contents

4 Case Study

The Spatial Decision Support System for the 27 municipalities around the Partenio Regional Park in Italy (Fig. 2) aims at simplifying the knowledge process of the landscape's tangible and intangible assets in order to recognize the relationships among these assets and to provide guidelines for the DM about the enhancement and the local network strategy. A multidimensional approach focused on the recognition of environmental, social, economic and cultural assets, was chosen and it has made possible to compare some strategies of enhancement with each smart domain for the overviewed landscape.

The above-mentioned steps of the data gathering and indicators processing (steps from 1 to 3) led to identifying the representation model and the process model. The classification of the indicators according to smart domains, indeed, brought to identify an evaluation model composed of six composite maps (steps from 4 to 8) and two final scenario maps (steps 9 and 10).

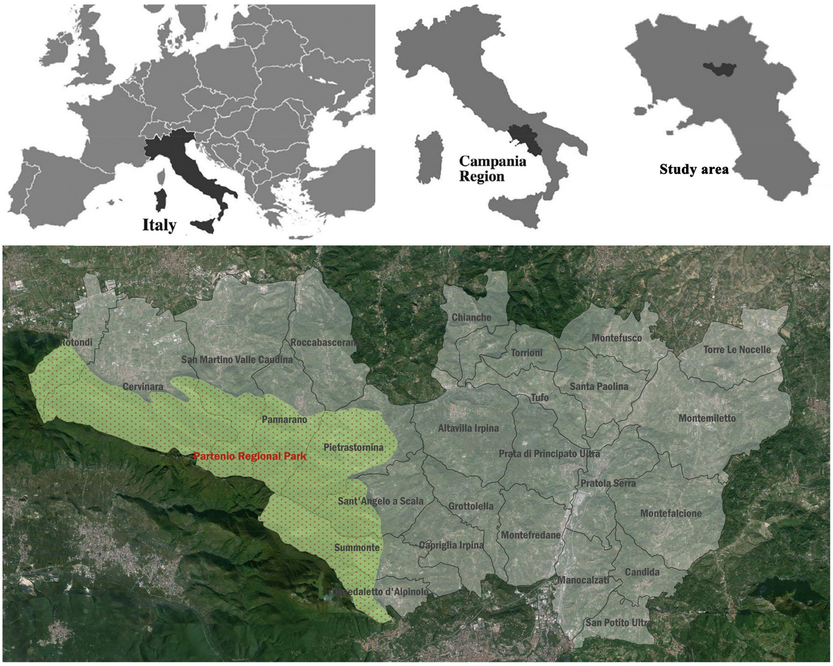

Fig. 2. The study area: 27 municipalities around the Partenio Regional Park in Italy

4.1 The Representation and the Process Models

In the following subsections, the six smart domains (Sect. 3) were synthetically described according to the meaning of each domain and the indicators developing the representation model, and the process model. In Table 1, the structure of the indicators

Table 1. The spatial indicators set categorized into smart domains

Domain	Indicator	U.M.	Year	Source	ID
Economy	Number of beds/Km^2 (Tourism index)	num.	2015	field research	ECO_1
	Mean price of accommodations	€	2015	field research	ECO_2
	Density of accommodations in 5 km	num.	2015	OSM/Web	ECO_3
	Density of food services in 5 km	num.	2015	OSM/Web	ECO_4
	Number of employers in tourism	num.	2009	dps.gov.it	ECO_5
	Number of wine firms	num.	2015	galpartenio.it	ECO_6
	Mean value of agricultural soils	€/ha	2015	CLC/Agenzia delle Entrate	ECO_7
	Number of people with income	num.	2011	ISTAT	ECO_8
Environment	Safeguard surface	ha	2015	Natura 2000	ENV_1
	Density of interest sites in 5 km	num.	2015	OSM	ENV_2
	Ecological integrity index	num.	2012	CLC	ENV_3
	Uninhabited houses	num.	2011	ISTAT	ENV_4
	Number of families in renting house	num.	2011	ISTAT	ENV_5
	Number of house owners	num.	2011	ISTAT	ENV_6
People	Number of people with master degree	%	2011	ISTAT	PEO_1
	Number of residents	num.	2011	ISTAT	PEO_2
	Housing density	Inh/Km^2	2015	ISTAT	PEO_3
	Youth index (20–35 age)	%	2011	ISTAT	PEO_4
	Old age index (over 65)	%	2011	ISTAT	PEO_5
	Employment rate	%	2011	ISTAT	PEO_6
	Unemployment rate	%	2011	ISTAT	PEO_7
Living	Number of months per municipality with cultural events	num.	2015	galpartenio.it	LIV_1
	Variety of cultural events	num.	2015	galpartenio.it	LIV_2
	Number of cultural events	num.	2015	galpartenio.it	LIV_3

(*Continued*)

Table 1. (*Continued*)

Domain	Indicator	U.M.	Year	Source	ID
	Number of municipalities with naturalistic path and itinerary	num.		OSM	LIV_4
Mobility	Class of accessibility per municipality	class	2009	dps.gov.it	MOB_1
	Presence or absence of a station per municipality	binary	2009	dps.gov.it	MOB_2
	Accessibility network	Km	2015	OSM	MOB_3
	People moving outside of their municipality	num.	2015	field research	MOB_4
Governance	Number of stakeholders	num.	2015	field research	GOV_1
	Number of projects	num.	2015	field research	GOV_2

is shown and the following fields are highlighted: domain, indicator's name, unit of measure (U.M.), year, source and ID (Table 1).

Economy. The "economy" domain aims at identifying the zones where the density of the economics and production for tourism development establish a spatial correlation. The selected local resources are classified in the following thematic areas and indicators: the accommodation (number, location, type, average prices); the quality of the agricultural production (number of wineries per municipality and market value of the agricultural soil) and the catering facilities. Specifically the indicator "value of the agricultural soils" (ECO_9) was built through the combination of the specific classes of CLC and the mean value of the land provided by the institutional dataset of the Italian "Agenzia delle Entrate". This processing has made spatially explicit the approximated quality of the agricultural production. Furthermore, some indices as the density of accommodation and catering facilities were processed through the Kernel Density Estimation method in order to build the process model. The geostatistics tool assesses the number of point events per unit of surface within a point-pattern (O'Sullivan and Unwin 2010). Therefore, the processing of point data produces new indicators on the areal surface of the landscape to identify the areas with the greatest concentration of tourism services (Fig. 3).

Environment. The "environment" domain includes both the potential and the weak components for the improvement of the touristic fruition. The natural and cultural landscape indicators were processed by the manipulation of the selected row data, i.e. the safeguard level of the natural surfaces and the ecological integrity index (van Berkel and Verburg 2014); furthermore the institutional dataset of the census zones provided information about the state of the housing abandon and the number of the family living in the analysis area. Same as above, the kernel density estimation identified the highest concentration of the touristic facilities points (Fig. 4).

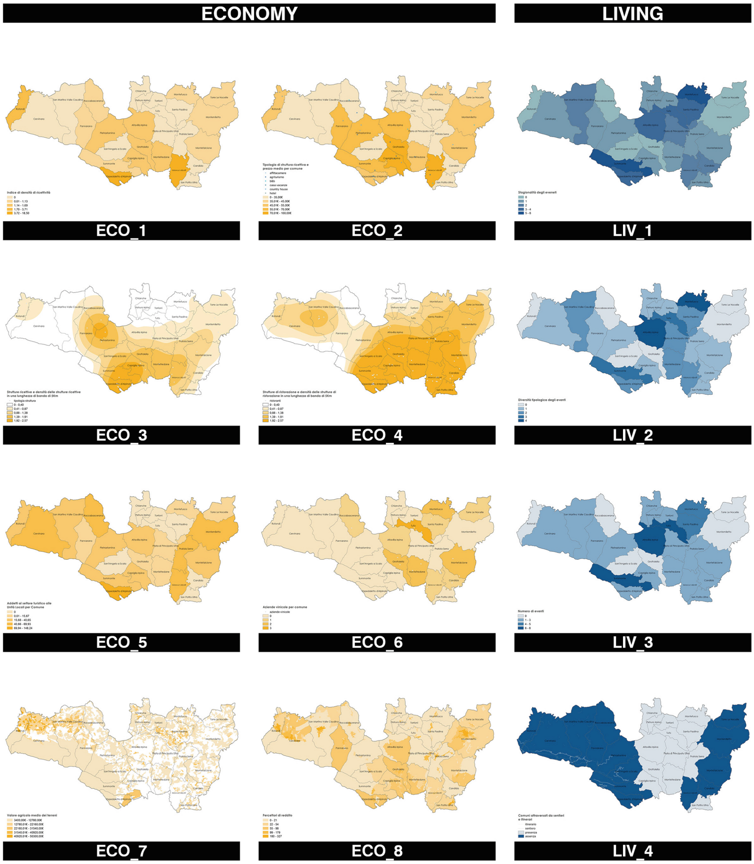

Fig. 3. Spatial indicators for “Economy” and “Living” domains: representation and process models

People. The “people” domain contains information about the population more exposed to the impact of the decisions. The indicators in this domain measure mainly the structure of the population per age and education. The major weakness of these indicators set is the MAUP. For this reason, while the “people” class is useful to understand the social and economic systems in order to build a broader and bright representation model, it is necessary to make a new indicators selection before proceeding to the multicriteria method application and evaluation (Fig. 5).

Living. The “living” domain aims at the identification of the cultural vitality of the examined region. The number of the cultural events and their type/frequency, the naturalistic path, the geographic itineraries were selected in order to identify the local resources improving the touristic network. The selected indicators in this category are samples of no spatially explicit criteria.

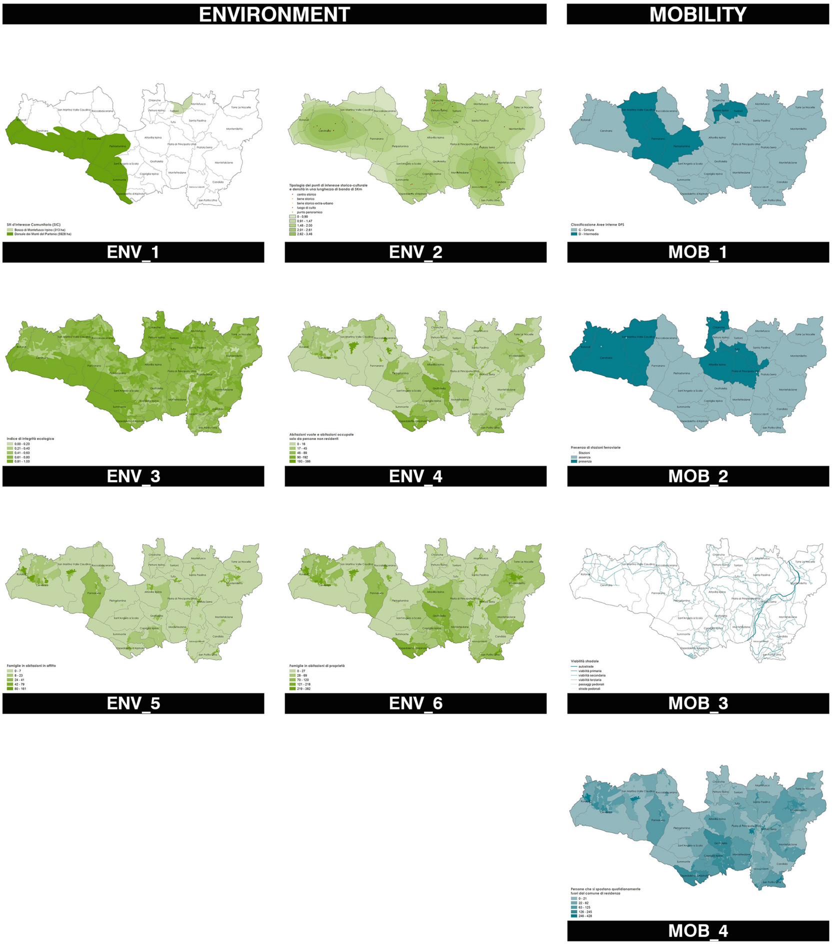

Fig. 4. Spatial indicators for "Environment" and "Mobility" domains: representation and process models

Mobility. The "mobility" domain shows the outside/inside accessibility of the municipalities. The indicators summarizing these issues was chosen within an institutional dataset that makes a classification of the municipalities according to the presence or absence of a railway station. In this regard, the number of railway stations and the other infrastructures of the study area were identified through different sources (Istat, DPS, OpenStreetMap). Furthermore, the number of people moving outside the municipalities was selected. Also in this category, the MAUP can be crucial.

Governance. Lastly, the "governance" domain contains indicators that measure the network of the stakeholders and the financing projects on the landscape.

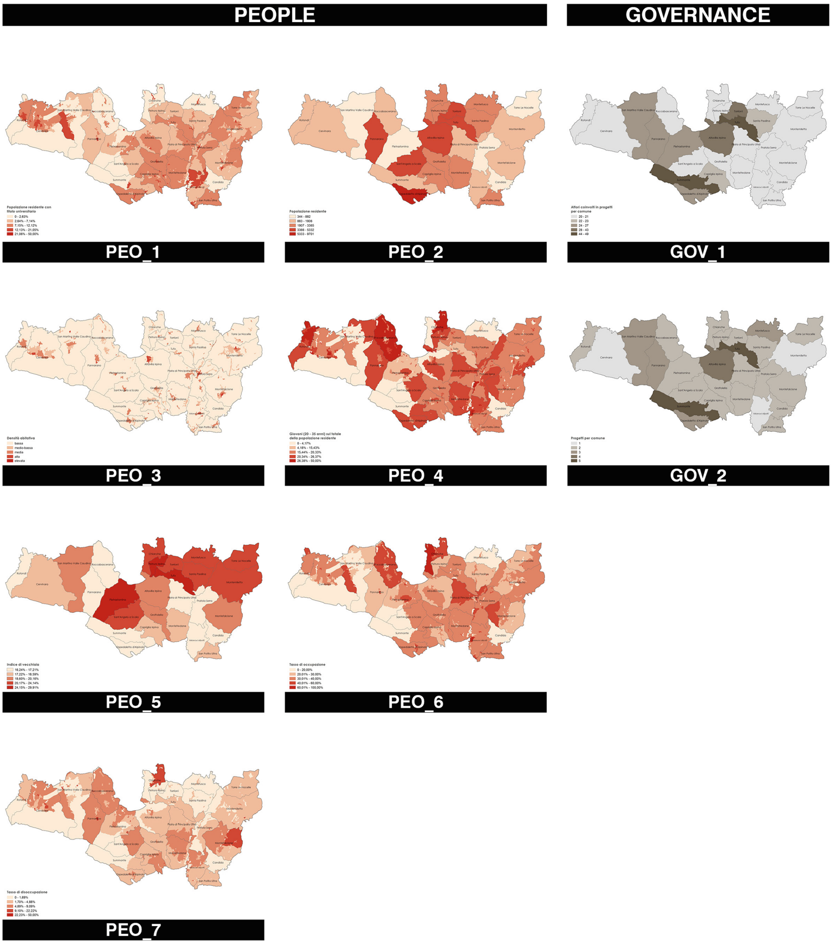

Fig. 5. Spatial indicators for "People" and "Governance" domains: representation and process models

4.2 Outcome: Two Evaluation Scenario for the Tourism Development Through WLC Method

The spatial indicators were worked out through the multi-criteria WLC method and six composite maps show the state of the local assets and the processes in the territory (Fig. 6).

According to the main purpose of the research, the weighting phase was implemented with the "swing weights method" (Bodily 1985). This method can be preferable when geographical data are available, since it simplifies the attributes outranking and weighting according to stakeholders preferences (Malczewski 1999).

The gradual scale of colours, from red to green, was chosen in order to identify areas with a different degree of suitability for tourism services development,

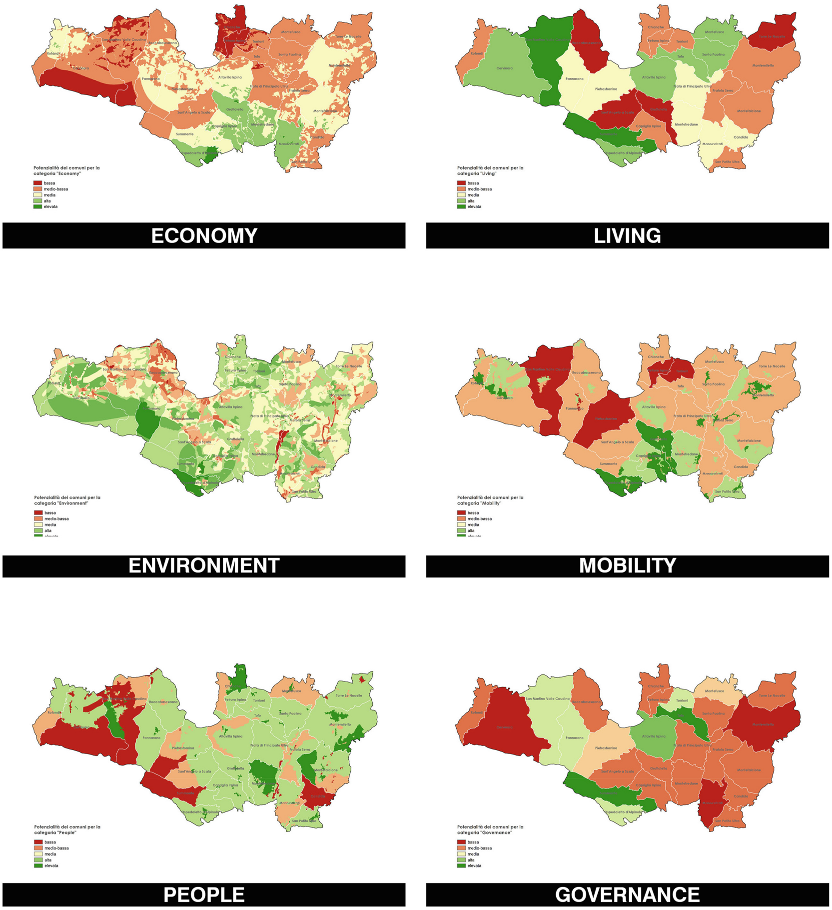

Fig. 6. Smart domains maps: weakness and potential of the study area through WLC method (Color figure online)

considering the red zones as negative and the green ones as positive, while the others mean intermediate values. The weighting phase provides two scenarios showing the suitable zones for tourism development according to the provided policy and planning strategies. The scenario 1, defined "Sulfur-Line" (Fig. 7), aims at improving the local resources through the wine and food paths strategy. This strategy is able to make explicit the history of the old mining quarries of the landscape, visiting naturalistic places and tasting local products.

The purpose aims at improving a network of municipalities to guarantee the touristic flows. The Table 2 shows the weights assigned to the scenario 1.

The scenario 2, defined "Welfare-Line" (Fig. 8), aims at fostering the religious and naturalistic tourism, implementing the quality of life through the preference of a slow-mobility, the enhancement of the amenities and the use of the touristic path and guides in the Partenio Regional Park.

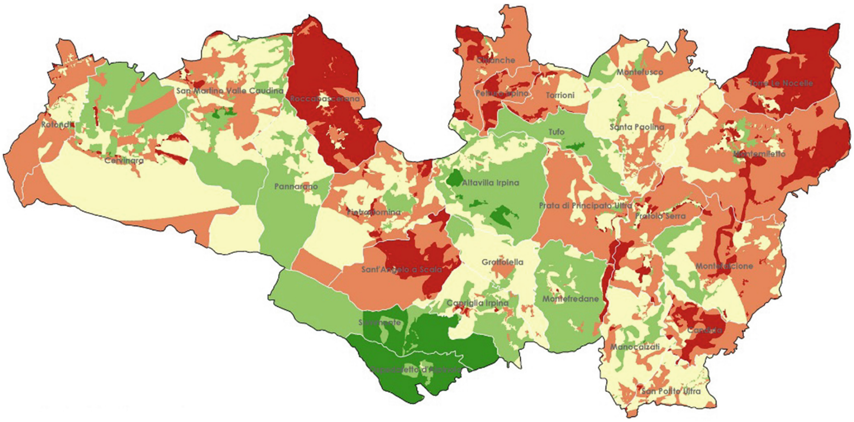

Fig. 7. Scenario 1 "Sulfur-Line". The gradual scale of colours, from red to green, allows to identify areas with major functioning of the tourism development strategy, considering the red as low and green as high, while the others mean intermediate judgments (Color figure online)

Table 2. Scenario 1 "Sulfur-Line". Weights of the domains

Ranking	Domain	Weight	
1	Environment	0,245	0,49
	Living	0,245	
2	Economy	0,165	0,33
	Mobility	0,165	
3	People	0,09	0,18
	Governance	0,09	

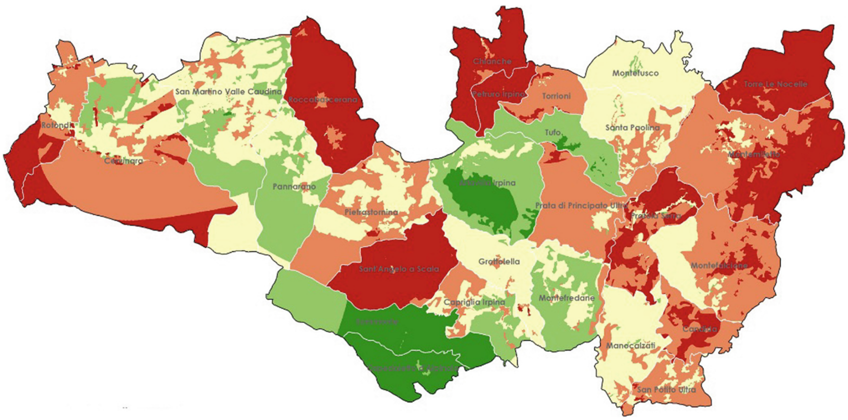

Fig. 8. Scenario 2 "Welfare-Line". The gradual scale of colours, from red to green, allows to identify areas with major functioning of the quality of life enhancement strategy, considering the red as low and green as high, while the others mean intermediate judgments (Color figure online)

The Table 3 shows the weights assigned to the scenario 2.

Table 3. Scenario 2 “Welfare-Line”. Weights of the domains

Ranking	Domain	Weight	
1	Economy	0,245	0,49
	Living	0,245	
2	Governance	0,165	0,33
	Mobility	0,165	
3	People	0,09	0,18
	Environment	0,09	

5 Conclusions

In the paper, it has been tested the SDSS for landscape evaluation. Its methodological approach wants to improve the acknowledgement of the complex values of the landscape, by defining a model of representing and processing data. These models have made possible to draw up appropriate spatial indicators for both geographical explicit data and implicit ones. This has improved the understanding of the landscape resources and transformation ways ongoing in the municipalities around the Partenio Regional Park.

By integrating, thus, data coming from public sources with VGIs’, it has been given a picture of the information on the context and the touristic enhancement goals. In details, the arranging of the information by following the domains of smart grammar aims to supervise available resources and the vigour of the place, highly regarding both environmental preservation and the needs of inhabitants and tourists. The issues dealt so far are about the geographical acknowledgement of the information and the chance to improve it through open source data.

The fact-finding survey developed here can be, therefore, improved and refined by users’ contribution. The tested SDSS opens the path to public debate on future scenario. Specifically, those simulated in step 9 and 10 allow a preliminary evaluation of the policies and the planning strategies currently in action. Thus, the scenario maps show new geography of complex values, where the green colour areas have the major opportunity about the functioning of the tourism development strategy, while the intermediate colour areas can be understood as a bridge among the strong zones and the weak one.

References

Attardi, R., Pastore, E., Torre, C.M.: Scrapping of quarters and Urban renewal: a geostatistic-based evaluation. In: Murgante, B., et al. (eds.) ICCSA 2014, Part III. LNCS, vol. 8581, pp. 430–445. Springer, Heidelberg (2014)

Bodily, S.E.: Modern Decision Making: A Guide to Modelling with Decision Support Systems. Mcgraw-Hill College, New York (1985)

Brown, G., Weber, D.: Public participation GIS: a new method for National Park planning. Landscape Urban Plan. **102**(1), 1–15 (2011)

Cerreta, M.: Thinking through complex values. In: Cerreta, M., Concilio, G., Monno, V. (eds.) Making Strategies in Spatial Planning. Knowledge and Values, vol. 9, pp. 381–404. Springer, Dordrecht (2010)

Cerreta, M., Fusco Girard, L.: Human smart landscape: an adaptive and synergistic approach for the National Park of Cilento, Vallo di Diano and Alburni. Agric. Agric. Sci. Procedia **8**(5), 489–493 (2016)

Cerreta, M., Inglese, P., Malangone, V., Panaro, S.: Complex values-based approach for multidimensional evaluation of landscape. In: Murgante, B., et al. (eds.) ICCSA 2014, Part III. LNCS, vol. 8581, pp. 382–397. Springer, Heidelberg (2014)

Cerreta, M., Poli, G.: A complex values map of marginal Urban landscapes: an experiment in Naples (Italy). Int. J. Agric. Environ. Inf. Syst. **4**(3), 41–62 (2013)

Cocco, C., Fonseca, M.B., Campagna, M.: Applying geodesign in Urban planning case study of Pampulha, Belo Horizonte. Braz. J. Cartography **67**(5), 929–940 (2015)

Fusco Girard, L., Cerreta, M., De Toro, P.: Integrated assessment for sustainable choices. Scienze Regionali **13**(1), 111–141 (2014)

Giffinger, R., Haindl, G.: Smart cities: ranking of European medium-sized cities. Centre of Regional Science (SRF), Vienna University of Technology, Vienna, Austria (2007)

Golub, A.L.: Decision Analysis: An Integrated Approach. Wiley, New York (1997)

Goodchild, M.F., Li, L.: Assuring the quality of volunteered geographic information. Spat. Stat. **1**, 110–120 (2012)

Istat: La nuova geografia dei sistemi locali, Istituto Nazionale di Statistica, Rome, Italy (2015)

Li, W., Li, L., Goodchild, M.F., Anselin, L.: A geospatial cyberinfrastructure for Urban economic analysis and spatial decision-making. ISPRS Int. J. Geo-Inf. **2**, 413–431 (2013)

Malczewski, J.: GIS and Multi-criteria Decision Analysis. Wiley, New York (1999)

Malczewski, J.: GIS-based multicriteria decision analysis: a survey of the literature. Int. J. Geogr. Inf. Sci. **20**(7), 703–726 (2006)

Murgante, B., Tilio, L., Lanza, V., Scorza, F.: Using participative GIS and e-tools for involving citizens of Marmo Platano - Melandro area in European programming activities. J. Balkans Near East. Stud. **13**(1), 97–115 (2011)

Openshaw, S.: The modifiable areal unit problem. CATMOG - Concepts Tech. Mod. Geogr. **38**, 3–41 (1983)

O'Sullivan, D., Unwin, D.J.: Geographic Information Analysis. Wiley, Hoboken (2010)

Steinitz, C.: A Framework for Geodesign: Changing Geography by Design. Esri Press, Redlands (2012)

Sugumaran, R., de Groote, J.: Spatial Decision Support Systems: Principles and Practices. CRC Press Taylor & Francis Group, Boca Raton (2010)

van Berkel, D.B., Verburg, P.H.: Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. Ecol. Ind. **37**, 163–164 (2014)

van der Sluijs, J.P.: A way out of the credibility crisis of models used in integrated environmental assessment. Futures **34**, 133–146 (2002)